Technical efficiency of small-scale honey producers in Ethiopia: A stochastic frontier analysis

LIVES WORKING PAPER 20

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May 2016

Editing, design and layout—ILRI Editorial and Publishing Services, Addis Ababa, Ethiopia.

Cover photo—ILRI/Aklilu Bogale

ISBN: 92–9146–469-4

Citation: Shiferaw, K. and Gebremedhin, B. 2016. *Technical efficiency of small-scale honey producers in Ethiopia: A stochastic frontier analysis*. LIVES Working Paper 20. Nairobi, Kenya: International Livestock Research Institute (ILRI).

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Acronyms

DEA	Data envelopment analysis
EBA	Ethiopian Beekeeper's Association
EHBPEA	Ethiopian Honey and Bee wax Producers and Exporters Association
PA	Peasant association

Acknowledgement

We would like to thank the Canadian Department of Foreign Affairs, Trade and Development (DFATD) for their financial support. We are also deeply grateful to the many farmers who patiently and willingly responded to our numerous questions.

Abstract

Using stochastic frontier production model, this paper tries to quantify the extent of technical efficiency and identify exogenous determinants of inefficiency. The results show that traditional practices dominate the sub-sector in Ethiopia. The findings also reveal that the use of purchased inputs such as bee forage and supplement is very limited among honey producers, indicating that natural bee forage is the primary source of food supply for bees. The immediate consequence of all these is low production and productivity. The number of hives a household owns, whether a household used improved apiculture technologies, availability of natural forest, which is the primary sources of nectar for bees, and amount of land owned by a households were found to have a significant influence on the amount of honey produced by beekeepers. Our results further show that the mean technical efficiency of honey producers is 0.79 implying that, on average, honey producers produce 80% of the maximum output. The implication is that 20% of the potential output is lost due to technical inefficiency. The number of hives owned by a honey producer, distance to district town, proximity to market access and household wealth, affect the technical efficiency of honey producers. The findings suggest that policies that aim to expand the use of improved hives are expected to increase the honey production at household level. The results also suggest that investment on rural infrastructure would be instrumental in improving technical efficiency of honey producers.

Key word: Small-scale honey producer, Ethiopia, technical efficiency in apiculture, stochastic frontier analysis

JEL Code: Q12. Q10. D13.C31

1. Introduction

Honey production is environmentally friendly practices and suitable for low income households. Particularly for rural households, beekeeping can coexist effortlessly with regular farming activities (Miklyaev et al. 2012).

Those engaged in beekeeping could earn income from production and marketing of honey and its by-products (bee wax, royal jelly, pollen, propolis, bee colonies, and bee venom). The sector could also create non-gender-biased employment opportunities. In addition to being a source of livelihood, due to their biological nature bee populations increase the crop productivity and conserve natural flora, since the insects pollinate crops, flowers and trees in their aerial roaming.

In Ethiopia, beekeeping and honey production is an ancient tradition that has been incorporated into Ethiopian culture. In fact, the country has been known for exporting bee wax for centuries (Gezahegne 2001) and the sector serves as an important source of livelihood for its rural population (Aklilu 2002).

Ethiopia is among the major producers of honey, both in Africa and the world. For instance, in 2013 the country produced about 45,000 tonnes which accounted for about 27% and 3% of African and world honey production respectively. This makes the country the largest producer in Africa and the tenth largest in the world (FAOSTAT 2015). Recent data indicates that the total volume of honey production is about 49,000 tonnes (CSA 2015).

Ethiopia has huge potential for honey production. Due to the availability of botanically diversified honey source plant species, honey produced in Ethiopia has a variety of natural flavours and this gives the country a competitive advantage. In addition, Ethiopian honey also has desirable qualities, such as low moisture content especially in drier areas, and absence of genetically modified organisms in the pollen which has been widely recognized in the international market (Gallmann and Thomas 2012). Furthermore, demand for honey and the other natural byproducts like wax and royal jelly remains high, which further makes the sector more promising to engage in.

Honey is produced in almost all parts of Ethiopia, with distinctive types of honey coming from different regions, mainly due to the type of bee forage available in the regions. Irrespective of where it is produced, honey in Ethiopia is primarily produced for the market. For instance, out of the total honey production, about 56% is destined to the market and the remaining portion is used for general consumption at household level (CSA 2014).

Another feature of honey production in Ethiopia is that other beekeeping products other than honey have been given less attention. Though bee wax is an important product of honey production, its production is limited because preparing and selling small quantities of bee wax is rather difficult for small beekeepers (Gallmann and Thomas 2012). Furthermore, the fact that it requires a sizable amount of capital to accumulate a sizable amount of wax for onward bulk sale also makes engaging in wax business difficult for small traders (ibid). As a result, it is underproduced by small-scale producers. Similarly, other hives products such as bee pollen, propolis, royal jelly and bee venom are also underproduced and the opportunity is under-exploited by small-scale beekeepers in Ethiopia.

Recognizing its potential contribution, the government of Ethiopia explicitly mentioned the sector in its medium-term growth plan (MOFED 2010). Furthermore, the sector has been incorporated into the working agenda of the government of Ethiopia, especially the Ethiopian Ministry of Agriculture (MoA), national research centres (Holeta, Andasa), and various non-governmental organizations. To help improve the sector and develop the honey value chain in the country the Ethiopian Honey and Bee wax Producers and Exporters Association (EHBPEA) and the Ethiopian Beekeeper's Association (EBA) has also been established.

Despite the long tradition of beekeeping in Ethiopia, being a leading honey producer, the availability of huge potential and the attention given to the sector, traditional production system is the main feature where 96% of the hives are reported to be traditional and 91% of the total honey produced comes from traditional hives (CSA 2015). The resulting low productivity in turn results in a lower contribution to the country's agricultural GDP. To increase the productivity of the sector, honey producer technical efficiency needs to be improved.

Thus, there is a need to understand the extent of technical efficiency and identify factors that exert influence on honey producer's performance. The result of such studies will enable policymakers design and implement effective policies and programs. Though there are studies on the sector (Gebremichael and Gebremedhin 2014; Gallmann and Thomas 2012; Miklyaev et al. 2012; Tessega 2009; Girma et al. 2008; Workneh et al. 2008; Aklilu 2002), none empirically investigated the extent of technical efficiency and identified the factors associated with it.

This study, therefore, has the objective of quantifying the extent of technical efficiency, as well as identifying the factors associated with the estimated farm-level inefficiency using a stochastic production function framework. Based on the findings of the study, policy recommendentions will be drawn.

2. Analytical framework

The paper focuses on the technical efficiency of small-scale honey production in Ethiopia. In economic terms, technical efficiency can be thought of as the ability to minimize input use in the production of a given output (Kumbhakar and Lovell 2000). In this sense, technical efficiency measures the actual output in relation to its optimal value as specified by a production function. A number of methodologies have been developed to measure efficiency.

Early authors such as Aigner and Chu (1968) and Førsund and Jansen (1977) used a deterministic models that attribute all deviations from the theoretical maximum solely to the inefficiency of producers. Then linear and quadratic programming methods have been suggested to compute the parameters of such models (Aigner and Chu 1968). One drawback of this approach is that the results obtained do not lend themselves to inferential analysis, as programming estimators do not produce standard errors for the coefficients (Greene 2008).

The above programming approach lays the foundation for the development of data envelopment analysis (DEA) by Charnes *et al*. (1978) and eventually supplanted by it (Greene 2008). DEA is a non-parametric and non-stochastic efficiency measurement technique.

DEA constructs a piecewise linear, quasi-convex hull around the data points in the input space. Then based on the constructed, quasi-convex hull, technical efficiency is measured by comparing observed producers with that of observed best practice. The main advantage of DEA is that it does not require assumptions about the form of the technology. However, this approach shares the same drawback of other deterministic estimators i.e. it attributes deviation of an observation from the frontier to inefficiency.

Motivated by the idea that deviations from the production frontier might not be entirely under the control of the producers being studied, a more flexible model called stochastic production frontier was developed notably by Aigner *et al*. (1977) and Meeusen and Broeck (1977). Under stochastic production frontier framework, it becomes possible to separately account for factors beyond and within the control of producers such that only the latter will be considered as technical inefficiency or a cause of inefficiency.

This approach redresses the main drawbacks of any deterministic frontier specification where random events such as bad weather as well as any error or imperfection in the specification of the model or measurement of its component variables might ultimately translate into increased inefficiency (Greene 2008). In addition, stochastic production frontier setting allows one to incorporate exogenous variables that exert influences on efficiency. Such analysis sheds light on factors associated with efficiency differentials among producers which is the main aim of this paper. Therefore, the paper utilizes a stochastic production frontier framework to measure technical efficiency and identify factors that explain efficiency differentials among small-scale honey producers in Ethiopia.

3. Model specification

To model output-oriented technical efficiency, we start by specifying a generic stochastic production function as follow (Kumbhakar and Lovell 2000).

$$y_i=f(x_i;\beta)*\exp\{\upsilon_i\}*TE_i \quad (1)$$

Where; y_i is the scalar output of producer i, i = 1,..., N, x_i is a vector of M inputs used by producer i, β is a vector of technology parameters to be estimated and TE_i is the output-oriented technical efficiency of producer i which provides a measure of the shortfall of observed output from the maximum feasible output. $f(x_i;\beta)$ is a deterministic part common to all producers, $\exp\{\upsilon_i\}$ is producer-specific random shocks, and $[f(x_i;\beta)*\exp\{\upsilon_i\}]$ is a stochastic production frontier.

In literature, the Cobb-Douglas and translog functional forms are widely used to represent the production function (Greene 2008). In this paper $f(x_i;\beta)$ is assumed to have a Cobb-Douglas form and its log linear form is given as

$$\ln y_i=\beta_0+\sum\beta_n \ln x_{in}+\epsilon_i \quad (2)$$

Where; $\epsilon_i=\upsilon_i-u_i$ is the composite error terms; υ_i, is the two-sided 'noise' component; and u_i is the nonnegative technical inefficiency component. By making distributional assumptions on υ_i and u_i the model parameters and thus the technical efficiency of each producer will be estimated.

Though different functional form has been used for υ_i and u_i in the application of stochastic production frontier analysis, following the work of Aigner et al. (1977) this paper makes the following distributional assumption about the error terms in eq (2). i) $\upsilon_i \sim$ iid $N(0,\sigma_v^2)$; ii) $u_i \sim$ iid $N^+(0,\sigma_u^2)$; that is, as nonnegative half normal; iii) υ_i and u_i are distributed independently of each other and of the regressors. The choice of half normal for u is further justified by the principle of parsimony.

Exogenous determinant of efficiency is introduced into the above models as a function of σ_u^2 (Kumbhakar et al. 2015). Formally,

$$\sigma_{(u,i)}^2=\exp(Z_i' w_i) \quad (3)$$

Where; Z_i' is a vector of exogenous variables that influence producer level technical efficiency and w_i, is the corresponding parameters vectors to be estimated. As argued by Kumbhakar et al. (2015) specifying exogenous efficiency determinant variables as a function of $\sigma_{(u,i)}^2$ permits solving two problems at once; correcting for one source of heteroskedasticity and incorporating exogenous influences on efficiency.

The log likelihood function of the stochastic production frontier models that incorporate exogenous determinants of efficiency is thus given as.

$$L_i=-\ln(1/2)-1/2\ \ln[\sigma_v^2+(\exp(Z_i' w_i))]+\ln\phi(\epsilon_i/\sqrt{(\sigma_v^2+(\exp(Z_i' w_i)))})+\ln\Phi(\mu_{*i}/\sigma_*) \quad (4)$$

Where; $\mu_{*i}=-(\exp(Z_i' w_i))\epsilon_i/\sigma_v^2+(\exp(Z_i' w_i))$ and $\sigma_*^2=(\exp(Z_i' w_i))\sigma_v^2)/(\sigma_v^2+(\exp(Z_i' w_i))$.

Stata is used to maximize the log likelihood function and estimate all the parameters. Then the technical efficiency index is computed using the formula given by (Battese and Coelli 1988).

$$TE_i=E[\exp(-u_i \mid \epsilon_i)]=\exp(-\mu_{(*i)}+1/2\,\sigma_*^2)\,\Phi(\mu_{*i}/\sigma_*-\sigma_*^2)/(\Phi(\mu_{*i}/\sigma_*) \quad (5)$$

Where μ_{*i} and σ_* are as defined in (4)

4. Empirical model

The analysis of technical efficiency in this study has two components. The first is the estimation of a stochastic production frontier that serves as a benchmark against which to estimate the technical efficiency of honey producers, while the second component identifies exogenous factors associated with the producer's performance in the production of honey.

Following the aforementioned discussion the empirical model of the production frontier equations is specified as follows.

$$\text{lnthon}=\beta_0+\beta_1 \text{ lnpinput}_i+\beta_2\text{lnntrdh}_i+\beta_3\text{lnntrnsh}_i+\beta_4 \text{ lnnmodh}_i+\beta_5 \text{ lnnforg}_i+\beta_6\text{lnland}_i+\beta_{37}\text{modh}_i+\beta_8 \text{ azzone}_i+ \epsilon_i \quad (6)$$

The dependent variable in the production function is the total honey produced by the household during the production season.

Explanatory variables in the production function equation

Bee forage and supplement used (lnpinput): Though not very common, small-scale honey producers in Ethiopia purchase bee forage seeds and plant them in apiaries as bee forage. Furthermore, during the dry season farmers use sugar and bean flours as feed supplements. It proves to be difficult to estimate the amount of these inputs in standard units such as kg. Instead, the total expenditure on bee forage, supplement and other inputs is included in the production function. The use of these inputs is expected to have a positive effect on the amount of honey produced by a household.

Number of hives (number of traditional hives (lnntrdh), number of transitional hives (lnntrnsh) and number of modern hives (lnnmodh)): Hives are the primary physical inputs needed for honey production. It is expected that the number of hives (traditional, transitional and modern) a household owns directly affects the amount of honey s/he produces. Thus, in the production function the number of traditional, transitional and modern hives the household owned was included.

Forest coverage of the area in hectare (lnnforg): The existence of forest and other vegetation is an important input for honey producers in the country. Honey producers that reside in an area where there is large forest coverage have access to ample nectar plants and thus are expected to produce more honey.

Land owned by a household (lnland): Land owned by a household is included in the production frontier equation since availability of crops that can serve as the sources of nectar for bees is directly related to the amount of land owned by a household. However, if a household with a large plot of land is engaged in intensive agriculture, they are more likely to use agro-chemicals that are harmful to bees. Thus, keeping all other things constant, the effect of land ownership on honey production could be either positive or negative.

Use of improved hives (modh): Like any agricultural activity the use of improved technology is expected to boost production performance. To capture the use of improved technology, a dummy variable (1 =use improved hive 0= otherwise) is introduced in the production function.

Agro-ecological zone (azzone): The agro-ecological zone of the area where farmers keep their bee hives is expected to have an effect on the amount of honey produced by honey producers primarily through its effect on the availability of bee forage and water. However, the effect of agro-ecological zone of the area on honey production is not clear since there are different bee species in the country with different adaptation capacities to different agro-ecological zones (Amssalu et al. 2004). Agro-ecological zones are introduced in the production function as a dummy variable where 1 for high land areas (above 1500 m asl) and 0 for lowland areas (below 1500 m asl).

Explanatory variables in the efficiency effect equation

To identify possible determinants of inefficiency, the following model is specified.

$$\sigma_{ui}^{2}=\exp(w_0+w_1 hhsex_i+w_2\ hhage_i+w_3 hhysch_i+w_4 hhsize_i+w_5\ hhwealth_i+w_6\ tothive_i+w_7\ distwt_i+w_8\ exten_i) \quad (7)$$

The exogenous variables expected to exert influence on the technical efficiency of honey producers include: sex (hhsex), age (hhage), and education status of the household head (hhysch), household size (hhsize), household wealth (hhwealth), total number of hives (tothive) and household access to institutions, such as market (distwt) and extension service (exten).

These exogenous variables are expected to affect producers' performance either through their influence on the structure of the technology by which inputs are converted to outputs, or through their influence on the efficiency with which inputs are converted to outputs (Kumbhakar and Lovell 2000).

5. Results and discussion

The data used in this paper is drawn from LIVES[1] baseline survey conducted in 2014. From the baseline dataset, those households who engaged in honey production were considered for this analysis.

5.1 Descriptive results

This section presents the descriptive results of household characteristics, input use in apiculture production, volume of production and productivity, as well as the gender role in apiculture production.

Household characteristics

The analysis of this paper is based on the data collected from 556 rural households (Table 1) selected from the four largest regions of the country (Tigray, 183; Amhara, 193; Oromia, 117; and SNNP, 63). In total, female-headed households constitute only 6.1% of the sample households. However, their share is higher in the Tigray region, revealing the difference in women's participation in apiculture production across regions.

Table1: Number of households engaged in honey production

Region	Male		Female		Total
	No of households	%	No of households	%	
Tigray	162	88.5	21	11.5	183
Amhara	186	96.4	7	3.6	193
Oromia	113	96.6	4	3.4	117
SNNP	61	96.8	2	3.2	63
Total	522	93.9	34	6.1	556

Traditional practice dominates honey production in Ethiopia and this is attested by our data where only 36.5% (203) of the sample households own improved bee hives (transitional or modern) (Table 2). Interestingly, however, only

1 Livestock and Irrigated Value chains for Ethiopian Smallholders (LIVES)—an ongoing collaborative research for development project implemented by International Livestock Research Institute (ILRI), International Water Management Institute, the Ministry of Agriculture, the Ethiopian Institute of Agricultural Research, the Ethiopian Ministry of Agriculture, regional bureaus of agriculture, livestock development agencies, regional agricultural research institutes—aims to improve competitiveness, sustainability and equity in value chains for selected high-value livestock and irrigated crop commodities in four regions (Tigray; Amhara; Oromia; and Southern Nations, Nationalities, and Peoples (SNNP)) of Ethiopia. Supported by Foreign Affairs, Trade and Development Canada (DFATD) the project is expected to end in March 2018.

As part of the project monitoring and evaluation framework a baseline survey was conducted in February April 2014 on 5000 households, randomly selected, using a multistage cluster sampling techniques from the 10 project zones. Using electronic data collection method detailed data on socio-economic status and agricultural activities of the households during past production season (June 2012–July 2013) were collected. The surveys were led by senior scientists from ILRI (project website: http://lives-ethiopia.org)

35.2% of male-headed households (184 out of 522) owned improved bee hives compared to 55.8% of those headed by women (19 out of 34) and the difference was found to be statistically significant (p = .045, two-tailed Fisher's exact test). This is probably because among other things, handling traditional hives requires physical strength, which limits the women's participation. On the other hand, notwithstanding the intensive management requirement, the modern hives are relatively women friendly.

Table 2: Distribution of beehives by sex of household head

Sex of household head	Beehive type					
	Traditional		Transitional		Modern	
	No of households	%	No of households	%	No of households	%
Male	408	78	21	4	163	31
Female	20	59	1	3	18	53
Total	428	77	22	4	181	33

Hives ownership

On average, a household owns about 3.37 beehives (Table 3). Disaggregation by gender shows that male-headed households own slightly more hives than their female counterparts (3.4 as compared to 2.85). However, the difference was found to be statistically insignificant (t= .729, p = .466). Studies show that in the rural Ethiopia, female-headed households have less access to productive assets such as beehives. However, the fact that our data detect no difference in number of beehives ownership between male- and female-headed households could indicate the success of the government and other developing partners working in the study area in targeting women and female-household heads.

Table 3: Number of hives per household

Sex of household head	No of households	Mean	Standard Deviation	Minimum	Maximum
Male	522	3.40	4.35	1.00	40.00
Female	34	2.85	2.62	1.00	11.00
Total	556	3.37	4.27	1.00	40.00

Analysing hives ownership by beehive type reveals that a household on average owns 3.37 traditional, 3.27 transitional and 2 modern beehives (Table 4). Test results indicate that the difference is statistically significant (F=8.499, p = .000). This is expected because traditional method of production dominate the apiculture sub-sector. In addition, the fact that improved hives are expensive further limits ownership of modern hives.

Table 4: Ownership of beehives per households by types of hive

Type of hives	Male		Female		Total	
	Mean	No of households	Mean	No of households	Mean	No of households
Traditional beehive	3.41	408	2.50	20	3.37	428
Transitional beehive	3.24	21	4.00	1	3.27	22
Modern beehive	1.94	163	2.39	18	1.99	181

Input use in honey production

Further indication of the widespread of traditional practices in honey production is the limited use of purchased inputs, such as bee forage and other supplements. As shown in Table 5, only 31.1% (173) of the sample households used purchased apiculture inputs in the production period. Though the proportion of male-headed households who used purchased inputs seems to be less than to that of their female counterparts (30.8% compared to 35.5%), the difference was found to be statistically insignificant (chi square with one degree of freedom 0.295, p=0.587). This shows that irrespective of the gender of the household head the use of purchased input is limited.

Table 5: Use of purchased/hired inputs in apiculture production

Sex of household head	Yes		No		Total
	No of households	%	No of households	%	
Male	161	30.8	361	69.2	522
Female	12	35.3	22	64.7	34
Total	173	31.1	383	68.9	556

Though the use of purchased input is limited in general, our analysis shows that compared to those who own traditional beehives, a higher proportion of households who own improved beehives used purchased inputs (28.3% compared to 43.3%) in the production of honey during the production season (Table 6). This is because, as mentioned above, improved hives require intensive management and need additional inputs such as wax. The implication here is that the development of the apiculture sector should follow a holistic approach such that the introduction of improved beehives, for example, should be coupled with improved access to apiculture inputs.

Table 6: Use of purchased/hired input in apiculture production by types of hives

Type of hives	Yes	%	No	%	Total
Traditional	121	28	307	72	428
Transitional	15	68	7	32	22
Modern	73	40	108	60	181

Disaggregation at regional level shows that the proportion of households that used purchased apiculture inputs is limited which ranges from 23.3% in Amhara to 44.4% in SNNP (Table 7) and the difference was found to be significant (chi square with three degrees of freedom is 11.650 and p=0.009). This could indicate difference in access to inputs among regions or difference in household practices. To disentangle the exact reason for the observed difference in use of purchased input among regions further studies are needed.

Table 7: Use of purchased/hired input for apiculture production by region

Region	Yes		No		Total
	No of households	%	No of households	%	
Tigray	59	32.2	124	67.8	183
Amhara	45	23.3	148	76.7	193
Oromia	41	35.0	76	65.0	117
SNNP	28	44.4	35	55.6	63
Total	173	31.1	383	68.9	556

Beehives are the most common purchased apiculture inputs by the sample households. Of those who used purchased inputs (173) about 52.6% (91) purchased hives during the production season (Table 8). This could be related to the availability of inputs as the district/woreda office of agriculture makes beehives available to farmers. On the other hand, only 19.7% (34 households) and 16.2% (28 households) used purchased bee forage and supplement feed respectively. A number of factors could explain the limited use of purchased bee forage and supplement, including a lack of supply of inputs, a limited economic access to inputs or low demand for purchased inputs because of availability of adequate bee forage in particular areas.

Table 8: Common types of input purchased/hired for apiculture production

Type of input	Sex of household head				Total	
	Male		Female			
	Number	%	Number	%	Number	%
Beehives	85	52.80	6	50.00	91	52.60
Bee colonies	42	26.09	6	50.00	48	27.75
Labour for bee management	39	24.22	2	16.67	41	23.70
Bee forage	31	19.25	3	25.00	34	19.65
Supplemental feed	26	16.15	2	16.67	28	16.18
Bee keeping accessories	10	6.21	3	25.00	13	7.51
Others	22	13.66	3	25.00	25	14.45

Of those who used purchased apiculture input excluding hired labour (154), a household on average spend about ETB[2] 677.02 during the production year and there is a high variation among households as confirmed by the huge standard deviation (Table 9). Though the average cost of purchased inputs is ETB 672.16 for male- and ETB 734.58 for female-headed households, the difference in average value of purchased inputs is not statistically significant for male- and female-headed households (t= -.197, p = .844). This is surprising given the fact that access to productive resources, credit and input market is different for male and female households in the rural setting (Quisumbing 1996; Udry et al. 1995).

Table 9: Value of purchased/hired inputs for apiculture production

Sex of household head	No of households	Mean	Standard deviation	Minimum	Maximum
Male	142	672.16	1076.24	18.00	7900.00
Female	12	734.58	749.57	50.00	2225.00
Total	154	677.02	1052.67	18.00	7900.00

Excluding hired labour, out of those who own traditional hives 103 households use some type of purchased inputs and on average spend about ETB 252.1 during the production season (Table 10). The big cost item was found to be bee colonies (ETB 653.6) followed by beehives (ETB 102.3). On the other hand, for beehives and bee colonies a household spends about ETB 192.5 and ETB 500 for transitional and ETB 663.4 and ETB 1,303.3 for modern beehives rspectively. Further analysis indicates that the difference in average expenditure between traditional and improved hives is statistically significantly only for beehives (t = -3.776, p = 0.004). This is because improved hives are much expensive than the traditional ones which are generally constructed from locally available materials.

Apart from the naturally available bee forage, honey producers also purchase improved bee forage. In this regard households who own traditional hives spend about ETB 67 on bee forage whereas those who own improved hives spend about ETB 84 and the difference is found to be statistically significant (t = -2.381, p = 0.025). The difference in use of purchased forage could be attributed to the fact that those who own traditional hives mainly depend on naturally available forage.

2 ETB 1= USD 0.00488 as of 2 June 2015

Overall, the data reveals that use of purchased inputs is related to the types of beehive a household owns (chi square with two degrees of freedom is 8.4206 and p=0.015). As can be seen in Table 10 irrespective of input type, those who own improved beehives are more likely to use purchased inputs than those who own traditional ones. This could be because compared to improved hives (transitional and modern), traditional beehives require less purchased inputs (Gebremichael and Gebremedehin 2014).

Table 10: Common type of purchased/hired inputs by types of hives

Type of input	Traditional		Transitional		Modern	
	Average (in ETB)	No of households	Average (in ETB)	No of households	Average (in ETB)	No of households
Beehives	102.3	49	192.5	8	663.4	46
Bee colonies	653.6	25	500.0	3	1303.3	27
Supplemental feed	71.8	13	34.8	2	138.2	21
Bee forage	67.0	26	40.3	3	82.8	12
Others	153.8	12	190.0	1	205.5	23
	252.1	103	244.3	14	1069.7	70

Honey production and productivity

In the production season, a household on average produces about 25.14 kg of honey (Table 11). Though the data seems to suggest a slight difference between male- (24.86 kg) and female-headed (29.43) households, the test results indicate that the difference is not statistically significant (t = -.845, p = .398). This is consistent with the results presented in tables 4 and 8 above which showed in significant differences in total number of hives owned and use of purchased inputs between male and female households.

Table 11: Total honey production (in kg)

Sex of household head	No of households	Mean	Standard deviation	Minimum	Maximum
Male	522	24.86	30.54	2.00	284.00
Female	34	29.43	30.65	3.00	114.00
Total	556	25.14	30.54	2.00	284.00

From traditional hive a household produces 5.7 kg per hives (Table 12) and the yield ranges from 2–15 kg. The data seems to suggests that female-headed households produce slightly higher honey per hive than their male counterparts (6.46 kg compared to 5.63 kg). However, test results failed to provide conclusive evidence to ascertain the fact that the difference in productivity between male- and female-headed households is statistically significant (t = -1.96, p = .050).

The yield from improved hives (transitional and modern) is found to be higher than the traditional ones and the difference was found to be statistically significant (F=305.86, p = .000). A household produced 13.77 kg and 16.01 kg per hives from transitional and modern hives. Though there seems to be a slight difference between male- and female-household heads, the difference was found to be insignificant both for transitional (t = .840, p = .411) and modern hives (t = -.016, p = .988).

Table 12: Honey productivity by types of hives

Type of hives		Mean	Standard deviation	Minimum	Maximum	No of households
Traditional beehive	Male	5.63	2.42	2.00	15.00	408
	Female	6.46	3.33	2.50	13.50	20
	Total	5.67	2.47	2.00	15.00	428
Transitional beehive	Male	13.95	4.60	4.00	20.00	21
	Female	10.00	.	10.00	10.00	1
	Total	13.77	4.57	4.00	20.00	22
Modern beehive	Male	16.01	8.06	8.33	55.00	163
	Female	16.04	7.38	8.50	35.00	18
	Total	16.01	7.98	8.33	55.00	181

During a production year, there are three honey harvesting seasons. The seasons are directly related to the availability of flowering trees and plants which are the source of nectar which in turn correspond to the amount of rainfall. Higher rainfall is associated with abundant flowering plants. Thus, in the main harvesting season, honey production is expected to be higher. As can be seen in Table 13, irrespective of hives type, production per hives is higher during the main season followed by short rainy season and dry season. On average, a household produces about 4.66 kg of honey per hive from tradition hives in the main season and the yield decreases to 2.78 kg per hive in the short rainy season and further decreases to 2.15 kg in the dry season. The same trend is observed for transitional and modern hives.

As compared to the short rainy and dry seasons, the number of honey producers is also higher during the main harvesting season. A total of 416 households harvested honey from traditional beehives during the main season. However, only 150 households harvested during the short rainy season and the number of producers drastically decreased in the dry season and reached 56. The same pattern is observed for transitional and modern hives, as well as for male- and female-headed households. A lack of bee forage could be the main reason as to why the yield and the number of producers decreases during the short and dry harvesting season.

Table 13: Honey yield across different season (kg/hive)

Hive type		Main season		Short rainy season		Dry season	
		Average yield	N	Average yield	N	Average yield	N
Traditional beehive	Male	4.66	398	2.78	141	2.15	50
	Female	4.92	18	3.45	9	1.97	6
Transitional beehive	Male	11.9	21	5.67	6	4.5	2
	Female	10	1	.	0	.	0
Modern beehive	Male	13.54	160	10.24	36	8.64	11
	Female	12.78	18	7.8	5	12.5	2

On average, a household gets about 5.55 kg, 13.37 kg and 16.01 kg of honey per traditional, transitional and modern hive (Table 14). Though the use of purchased inputs is expected to increase yields, the difference in yield between those who used purchased inputs and those who did not was found to be statistically significant only for modern hives ($t = -2.3856$, $p = 0.018$). This seems to suggest that the use of purchased inputs does not have a positive effect on honey production under traditional beekeeping management. However, it should be noted that the type of inputs used and the intensity of input use under traditional bee keeping is very different from that of modern beekeeping practices.

Table 14: Honey production (kg/hive) by use of purchased/hired inputs

Type of hives	Use of purchased input	No of households	Mean	Standard deviation	Minimum	Maximum
Traditional beehive	No	324	5.62	2.48	2.00	15.00
	Yes	124	5.38	2.50	2.00	13.50
	Total	448	5.55	2.48	2.00	15.00
Transitional beehive	No	12	13.04	5.18	4.50	20.00
	Yes	11	13.73	4.71	4.00	19.00
	Total	23	13.37	4.86	4.00	20.00
Modern beehive	No	114	14.94	7.23	8.50	47.00
	Yes	67	17.83	8.87	8.33	55.00
	Total	181	16.01	7.98	8.33	55.00

Since it requires low startup investment, beekeeping is accessible to the poor and vulnerable. However, our data reveals that in the majority of cases, head of the households who are often adult males are responsible for the production of honey (Table 15). It is quite understandable that the role of women is limited in the traditional apiculture production as it require physical fitness to put the hives in place and harvest honey. However, the limited involvment of women in modern beekeeping indicates a missed opportunity that should have been seized.

Table 15: Responsibility of honey production by type of hives

Who is involved in apiculture production	Traditional beehive		Transitional beehive		Modern beehive	
	No of households	%	No of households	%	No of households	%
Head only	336	79	17	77	158	87
Spouse only	9	2	0	0	5	3
Head and spouse	39	9	3	14	5	3
Head and/or male child	32	7	2	9	7	4
Other	12	3	0	0	6	3
Total	428		22		181	

5.2. Econometric results

A stochastic frontier specification was used to quantify the level of technical efficiency of small-scale honey producers. The third moment of the OLS residual test (M3T) of Coelli (1995) was conducted to check the validity of the model. The test results show that the OLS residuals are skewed to the left and this lends support to the stochastic frontier specification (Table 16).

Table 16: Estimation results of the stochastic production frontier and inefficiency effects model.

Production frontier function						
lntothon	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnpinput	0.023211	0.018304	1.27	0.205	-0.01266	0.059086
lnntrdh	0.372463***	0.036521	10.2	0.000	0.300884	0.444042
lnntrnsh	0.391742***	0.137867	2.84	0.004	0.121528	0.661956
lnnmodh	0.392462***	0.061534	6.38	0.000	0.271858	0.513066
lnnforg	0.028204*	0.014854	1.90	0.058	-0.00091	0.057316
lnland	0.130125***	0.039833	3.27	0.001	0.052054	0.208196
modh	0.774231***	0.077548	9.98	0.000	0.622239	0.926223
azzone	-0.08134	0.065831	-1.24	0.217	-0.21036	0.047692
cons	2.351325***	0.101235	23.23	0.000	2.152908	2.549741
Inefficiency effects model						
usigmas						
hhsex	1.019357	1.018005	1.00	0.317	-0.9759	3.014611
hhage	0.002337	0.017124	0.14	0.891	-0.03122	0.035899
hhysch	-0.02773	0.060076	-0.46	0.644	-0.14548	0.090012
hhsize	0.180136*	0.095672	1.88	0.060	-0.00738	0.367648
hhwealth	-9.98E-06	6.15E-06	-1.62	0.105	-2.2E-05	2.08E-06
tothive	-0.90627***	0.319411	-2.84	0.005	-1.5323	-0.28023
Distwt	0.00241*	0.001423	1.69	0.090	-0.00038	0.0052
Exten	0.241996	0.389373	0.62	0.534	-0.52116	1.005154
cons	-3.03526**	1.569789	-1.93	0.053	-6.11199	0.041473
vsigmas						
_cons	-1.0547	0.074123	-14.23	0.00	-1.19998	-0.90942
L. Likelihood	-514.88121					
x^2	382.20					
N	545					
M3T Statistics	-1.5823319					

Note: * significant at 10%; * a significant at 5%; * a significant at 1%

As can be seen in Table 16 above, the results show that the number of hives a household owns, use of improved technology (modern hives), land owned by a household and availability of natural forest which is the primary source of nectar for bees are important inputs in the production of honey by small-scale producers in Ethiopia.

Irrespective of their types, the number of beehives were found to have a statistically significant effect (P<0.001) on the amount of honey a household produces. This shows that small-scale-farmers are underutilizing the available inputs and the optimal number of hive ownership has not been reached. The output elasticities of the hives are 37%, 39% and 39% for traditional, transitional and modern beehives respectively.

Availability of forest and other vegetation measured in terms of forest coverage per household has a positive and statistically significant effect (P<0.1) on the amount of honey produced by a household. In Ethiopia, forest plants and natural vegetation are the main sources of bee forage and our results reflect this rather clearly. The immediate implication of using naturally available vegetation as a primary source of bee forage is that there is a high input–output ratio which makes the sector even more suitable for low-income households.

Though honey production does not need large tracts of land, the results showed that the amount of land owned by a household positively affects honey production and the effect was found to be statistically significant (P<0.01). This could be because households that own large plots of land can afford to allocate more land for planting bee forage plants, which directly affect the amount of honey production.

Use of improved technologies, particularly use of improved hives, is also found to have a significant effect (P=0.001) on the amount of honey produced by a household. This is hardly surprising because compared to traditional hives the improved ones, both transitional and modern hives, allow farmers to increase honey production significantly.

On the other hand, use of purchased inputs (bee forage) was found to have statistically insignificant effect (P= 0.205) on the amount total honey produced by a household. This could be because farmers use purchased input as a form of coping mechanism during slack seasons when there is shortage of bee forage rather than to increase honey production.

Similarly, agro-ecological zone was found to have no statistically significant effect (P=0.217) on honey production. This is probably because there are different bee species in the country with different adaptation capacity to the different agro-ecological zones.

The mean technical efficiency is equal to 0.797 implying that, on average, honey producers produce 80% of the maximum possible output. In other words, about 20% of the potential output is lost to technical inefficiency. Here care should be taken in interpreting the technical efficiency score because the estimated technical efficiency is only relative to the best producers in the sample. Furthermore, as noted by Coelli et al. (2005) the estimated efficiency level provides no information about the efficiency of one sample relative to another. Therefore, it should not be used to compare the results with other samples as it only reflects the dispersion of efficiency within each sample.

To identify factors that influence technical efficency, exogenous factors were included in the efficiency effect model. The choice of variables used in this paper as potential determinants of efficency has been guided by relevant literature and data availability.

The number of total hives owned by household size, and distance to woreda towns, was found to have a statistically significant influence on the technical efficiency of honey producers. While household wealth was found to only have marginally significant effect.

A household that owns large number hives tends to be more technically efficient (P<0.001). This could be related to the advantages associated with economices of scale. Access to markets and other institutions, proxied by distance to woreda towns in this paper is expected to influence the efficiency level of honey producers. In this regard, the results show that honey producers located near to woreda towns are more efficient than households located very far and the difference was found to be statistically significant (P<0.1), probably because households who have access to markets and institutions could get technical knowledge and skills needed to produce honey more efficiently.

Surprisingly, access to extension services was found to have statistically insignificant effect on the technical efficiency of honey producers (P=0.534). This could indicate the ineffectiveness of the extension service that target small-scale honey producers. The result is in line with the findings of SOS–Sahel-Ethiopia (2006) which showed that the lack of adequate extension services in the area of honey production and marketing negatively affects the sub-sector.

6. Conclusions and implications

Though beekeeping and honey production started in Ethiopia a long time ago and the country has a huge potential for organic honey production, the production and productivity level of the sector is very low. This paper, therefore, tries to explore the status of honey production by small-scale producers, investigate the technical efficiency and identify factors that explain efficiency differentials among small-scale honey producers in the country by using a cross section data collected from 556 small-scale honey producers.

The paper uses descriptive statistics to explore the current status of small-scale honey production and a stochastic production frontier analysis to examine their technical efficiency. Test statistics suggested by Coelli (1995) have been conducted to check the validity of the stochastic frontier specification and the results support the use of a stochastic frontier model.

The results show that, consistent with other studies, traditional practices dominate small-scale honey production in Ethiopia. This is primarily reflected by the use of traditional hives by the majority of honey producers. Though different efforts have been made so far to introduce improved hives, these efforts were not effective. This presents both opportunities and challenges to ameliorate the sector. By replacing the traditional hives with the improved ones it is possible to increase production and productivity considerably. On the other hand, there is a need come up with suitable and feasible improved hives that are both accessible to small-scale farmers and easy to operate.

The finding also reveals that use of purchased inputs, such as bee forage and other supplements, is very limited among honey producers indicating that natural bee forage is the primary source of bee forage. This result is consistent with other research in the area (IMPS 2005).Though this presents a clear advantage in that honey produced from natural vegetation is organic and is free from agro-chemical contamination, being excessively dependent on naturally available forage makes honey producers more vulnerable to drought. In fact, a study by Workneh et al. (2008) found drought as the primary constraint honey facing producers in Ethiopia. A number of factors, including low levels of awareness about the existence of bee forage other than the naturally available ones, shortages of bee forage supply or limited access to commercially available forage could explain why small-scale honey producers excessively depend on natural vegetation. Though a detailed study is needed to identify the real reasons why small-scale honey producers depend on natural vegetation, the important point remains that to bring meaningful change the use of improved bee forage should be promoted.

As far as the volume of production and productivity is concerned, a clear message emerges from our analysis. Annual honey production was found be about 25.14 kg per household with no statistically significant difference between male- and female-headed households. The results further show that the amount of honey production directly correlates with the availability of bee forage.

On the other hand, on average, honey yield from traditional hives was found to be 5.7 kg, while 13.77 kg and 16.01 kg were harvested from transitional and modern hive respectively. The yield, particularly from modern hives, is found to be affected by the use of purchased input. Thus, the paper suggests that there is a clear connection between improved bee management and total production and productivity.

The results of the stochastic frontier model show that the number of hives a household owns, whether a household uses improved apiculture technologies and the availability of natural forest, the primary sources of nectar for bees, determine the amount of honey produced by small-scale honey producers in Ethiopia.

The fact that the number of hives determine the total amount of honey production shows that the current number of hives owned by small-scale honey producers is less than optimal. One of the primary reasons for operating a small number of hives, particularly improved ones, is the initial cost of the hives themselves and limited access to bee forage. Thus, there is a need to improve farmer access to credit services.

Use of improved technology is also found to have a significant effect on the total honey production. This could be used as another intervention point to improve the production and productivity of honey producers. In the past, a number of efforts have been made to introduce modern hives. However, the penetration rate was very low (Gallmann and Thomas 2012). The implication is that the importance of improved hives has long been recognized by policymakers and other development partners. The real hurdle in this regard is how to improve the adoption of improved hives. Gallmannand and Thomas (2012) argued that apart from their price, the difficulty of working with modern hives discouraged adoption. This is partly because more emphasis is given to increasing the supply of inputs rather than improving bee husbandry as a whole. Thus, from a technology perspective, there is a need to introduce improved hives that can be constructed from locally available material. Furthermore, these improved hives should not require specialized knowledge or skills to operate them. The extension service for its part should provide capacity building training to farmers on how to construct and maintain improved hives and also link them with credit service providers.

The importance of forest plants as a source of bee forage consistently show up in our analysis. In the stochastic frontier model, availability of forest plants measured in terms of area under forest coverage per household was found to have statistically significant effect on the amount of honey produced by a household. In this situation, small-scale honey producers would have no incentive to invest in improved bee forage since they can produce honey without incurring any cost, particularly from flowering plants. In this regard, it is important to convince honey producers about the importance of using improved bee forage and encourage them to grow improve bee forage. At the same time there is a need to expand the use of indigenous flowering plant and shrubs, as well as introduce improved bee forage seeds.

Technical efficiency of the honey producers considered in the analysis was found to be 80% indicating that about 20% is lost due to technical inefficiency, suggesting that in Ethiopia small-scale honey producers not only use less productive materials and inputs, but also produce even less than what is possible with those technologies and input set. Considering the traditional nature of honey production in the country, a technical efficiency of 80% may be interpreted as a reasonable performance. However, it should be noted that the estimated technical efficiency is only relative to the best producers in the sample.

The number of total hives, distance to woreda towns and household size, have a statistically significant influence on the technical efficiency of honey producers.

The findings suggest that policies that aim at increasing the total number of hives operated by honey producers are expected to increase farmer efficiency. Furthermore, investing in rural infrastructure, such as roads, would provide venues for ideas and technologies to flow from the centre to the periphery such that locational disadvantages of honey producers in remote villages could be overcome and thus enhance their efficiency level.

Ethiopia has untapped potential in the production and marketing of honey and other bee products. Furthermore, the sub-sector is suitable for small-scale producers, particularly for poor rural households that have limited livelihood opportunities. Thus, by redressing the constraints and adopting a more focused approach it is possible to increase the contribution of the sub-sector and at the same time benefit poor rural households.

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ISBN 92–9146–469-4

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